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AGRICULTURAL MEMORANDUM NO 481

AUTUMN WORK DAYS, MODEL I

C V Smith

1. INTRODUCTION

The initial study, with spring cultivations, was simply concerned with numerical relationships between weather and field work days. There was a minimum of physical interpretation of the data, the object being to identify criteria which would enable one to pass from observations of field work to observations of the weather, and vice-versa; the ultimate objective was that past records of weather should be capable of being reinterpreted as days available for field working. In this way, the distribution of work days over many years was to be established from very limited field work data.

The current problem is to suggest weather criteria for the days of autumn field working when work can proceed without the risk of structural damage to the soil.

In the spring, the production of a satisfactory seed bed implies a concern for soil fractions and soil structure; by contrast, in the autumn, the emphasis is often simply of the lifting of the current root crop. (Any attendant soil compaction or smearing is supposed to be capable of being remedied by later frost action). The search for patterns of response in recorded autumn field workdays to patterns of weather was not informative.

In order to develop criteria for autumn field working, one of necessity is thrown back onto an understanding of the relative order of magnitude of the physical processes involved in the soil moisture balance, to the development of a theoretical model and to a validation procedure which, in the end, may turn on subjective estimates of whether the number of field work days generated by the model appear reasonable.

2. MODEL I AND THE THOUGHTS BEHIND IT

We here define an Autumn Work Day as one on which normal field working carries only a slight risk of structural damage to the soil; field work in the present context is restricted to the primary cultivations and soil movement necessary for the autumn sowing of crops.

We assume the risk of structural damage before a return to field capacity is minimal and concern ourselves only with the risk after this time.

Dry soils are able to support heavy loads, because of the rigidity of the individual soil particles and the high internal friction of the soil mass. Added water reduces the internal friction, making the soil susceptible to plastic deformation and consolidation. As water content is further increased, the soil takes on the properties of a fluid and loses its load bearing properties entirely.

Evidently our problem involves us in an examination of soil moisture and a balance equation of the form

$$\text{Precipitation } (P) - \text{Run off } (S) = \text{Surface detention of moisture } (D) + \text{Change in stored soil moisture } (M) + \text{Evaporative loss } (E) + \text{Through drainage } (U).$$

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We assume we are dealing with soil types in which a definite field-capacity can be established, that is with soils where excess water in the profile can be removed by drainage, and where at the end of the period of drainage, the total water content within a given depth of soil is approximately constant (for a given soil type). This assumption enables us to assign an upper limit to the value of M, the change in stored soil moisture, in our balance equation.

For simplicity in the initial model, but also for want of detailed information at this time, we set S, the surface run off, to be zero and require all rain that falls to pass into the soil. (This latter requirement also implies that D, the water retained on the surface of soil shall effectively be zero at the end of the time intervals that we consider - 1 day or more). We assume that soil structure is put at risk if work is attempted during a time when saturation (ie water in excess of that at field capacity) exists in the surface layer. The question now is how deep is this layer to be?

For a soil at field capacity throughout its depth, we take initially the depth of the surface layer to considered as 10 cms.

We consider the implications of our assumptions at a specific site, Cambridge.

3. DATA

Typical infiltration rates have been quoted as:

Very slow	< 0.01 m/day	ie < 10 mm per day
slow	0.01 to 0.1 m/day ie	10 mm to 100 mm per day
Moderate	0.1 to 1.0 m/day ie	100 mm to 1000 mm per day

Typical rainfall rates at Cambridge will seldom require anything more than a very slow infiltration rate for their removal by through drainage. For a 'Heavy' soil type we note that the excess water that can be drained from a saturated soil at field capacity is likely to be of the order 1.5% of the total volume of the soil (Russell 1950, p.353). (This information is based on a 20 inch drain gauge and the depth of soil considered now includes some subsoil). For a 10 cm depth of soil, at field capacity, the rainfall that will produce saturation of this layer is thus 1.5 mm (.06 ins).

For a 'Medium' soil type we assume that the corresponding rainfall that will produce saturation of the top 10 cm layer will be 2 x (1.5) mm = 3.0 mm (1.12 ins).

For a 'Light' soil type we assume that the corresponding rainfall that will produce saturation of the top 10 cm layer will be 5 x (1.5 mm) = 7.5 mm (.30 ins). In each case we assume that these are also the amounts of water that can be removed from the top 10 cm layer, by drainage in 24 hours.

Water will also be removed from this layer by evapo-transpiration. We assume that we can ignore the difference in evaporative water loss between a green crop cover, a surface layer of water and a bare, moist soil, and that a suitable, all-embracing figure to employ for evaporative water loss will be given by the Potential Transpiration.

Average Potential Transpiration amounts at Cambridge are:

September	1.95 ins/month	= .065 ins/day	= 1.65 mm/day
October	0.85	= 0.27	= 0.70
November	0.15	= .005	= 0.13
December	0.00	= .000	= 0.00
January	0.05	= .014	= 0.05
February	0.40	= .040	= 0.35
March	1.30	= .073	= 1.02

Suitable rainfall data are most readily available in the form shown in Table 1. These can be readily manipulated to give the average number of rain days within specified ranges for any month. If the data for any one month are plotted on logarithmic paper, then the approximately linear relationship found between frequency and daily rainfall totals enables an interpolation to be made for intermediate rainfall amounts.

4. A TYPICAL CALCULATION

We consider the month of September and a soil at field capacity.

HEAVY SOIL

From the top 10 cm of a Heavy Soil, some .065 inches of water will be removed by evaporation in one day; rainfall up to .06 inches can be removed by through drainage. The maximum daily moisture loss from the top 10 cm is thus put at (.065 + .06) = .125 inches.

We obtain the number of occasions, in the 35 fyear period 1916-1950 (Table 1), when the daily rainfall lay within various multiples of the maximum daily moisture loss from the surface layer.

DAILY RAINFALL RANGE	MULTIPLE	NUMBER OF OCCASIONS
.063 - .125 ins	$(\frac{1}{2} - 1)$	85
.125 - .250	$(1 - 2)$	102
.250 - .375	$(2 - 3)$	52
.375 - .500	$(3 - 4)$	22
> .500	> 4	34

(i) We assume that a daily rainfall amount in the first range prevents work on that day.

(ii) We assume a daily rainfall amount in the second range prevents work for that day.

(iii) We assume that a daily rainfall amount in the third range prevents work on that day and on the subsequent day.

(iv) We assume that a daily rainfall amount in the foruth range prevents work on that day and the 2 subsequent days.

(v) We assume that a daily rainfall amount in the fifth range prevents work on that day and the 2 subsequent days.

The number of days lost to work in the 35 Septembers is thus:

85 x 1	=	85
102 x 1	=	102
52 x 2	=	104
22 x 3	=	66
34 x 3	=	102
		459

Average work days lost in September = 13
Average work days in September = 17

MEDIUM SOIL (SEPTEMBER)

The maximum assigned daily water loss is now (.065 + .12) = .185 inches

Daily Rainfall Range	Multiple	Number of occasions	Work Days lost
.93 - .185 ins	(½ - 1)	100	100 x 1 = 100
.185 - .370	(1 - 2)	94	94 x 1 = 94
.370 - .555	(2 - 3)	29	29 x 2 = 58
> .555	> 3	27	27 x 3 = 81
			333

Average work days lost = 10
Average work days = 20

LIGHT SOIL (SEPTEMBER)

The maximum assigned daily water loss is now (.065 + .30) = .365 ins.

Daily Rainfall Range	Multiple	Number of occasions	Work Days lost
.183 - .365	(½ - 1)	97	97 x 1 = 97
.365 - .730	(1 - 2)	43	43 x 1 = 43
> .730	> 2	15	15 x 2 = 30
			170

Average work days lost = 5
Average work days = 25

Noting that the maximum period of interference with work, due to rain, is 3 days for Heavy and Medium soils and 2 days for a Light soil, then if similar calculations are done for the remainder of the months and extended into the spring period we obtain the following results:

TABLE 2

AVERAGE WORK DAYS (AFTER SOIL RETURNED TO FIELD CAPACITY)

Depth of soil considered - 10 cms

	Heavy	Medium	Light
September	17	20	25
October	13	19	24
November	8	16	23
December	10	19	26
January	6	15	22
February	11	17	24
March	21	23	27

Extension into the spring enables us to compare the results of the model against a completely independent set of work criteria, namely those derived from records of work days experienced by farmers under field conditions when soil structure was important.

The average number of such workdays over a 22 year period at Cambridge are obtained from Table 4 of Ag Mem 438, as

	Heavy Soil	Medium Soil	Light Soil
February	10	17	25
March	21	23	25

(The February figures of Table 4 of Ag Mem 438 are the work days available after February 19th, 18th, 17th for Heavy, Medium and Light Soils respectively. The figures set down above for comparison with Table 2 have been increased proportionally to cover the whole of February).

Repeating the calculations for other depths of soils gives the information brought together in table 3.

Table 3 Average Work Days (after soil returned to field capacity)

Depth of soil considered - 5 cms

Soil Type	Heavy	Medium	Light
September	15	16	22
October	5	12	21
November	0	5	18
December	0	8	21
January	0	7	19
February	9	14	21
March	19	22	25

Depth of soil considered - 10 cms

Soil Type	Heavy	Medium	Light
September	17	20	25
October	13	19	24
November	8	16	23
December	10	19	26
January	6	15	22
February	11	17	24
March	21	23	27

Depth of soil considered - 20 cms

Soil Type	Heavy	Medium	Light
September	17	24	28
October	18	24	29
November	15	22	28
December	18	25	29
January	17	24	29
February	19	23	27
March	25	27	30

5. Discussion

Our major interest must be in the heavy and medium type soils

(i) It would seem that with this model, a depth of 5 cms is not one that is realistic (no work days implied in the winter) and that the depth of soil to be considered should be at least 10 cms
With depths of soil greater than 20 cms, we begin to move towards the situation where everyday becomes a work day (and independent of the amount of rain that falls).

(ii) Objections have been made to the values for the soil porosity that have been used (1.5%; 3%; 7.5%) nd a more realistic figure, for the depths of soil we consider has been suggested as 20% (for all soil types).

(iii) With the soil depth of 10 cms, the model, when applied to the spring period gives a close fit with observed work days. It has been suggested that for this very reason, since the spring soil/seed bed requirements may be more demanding than in autumn, that the model at 10 cms is too restrictive for the autumn period and leads to an under-estimate of the time available for work at this season of the year.

(iv) Further comments would still be welcomed.

Meteorological Office
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TABLE 1

Accumulated Frequencies of Daily Rainfall (in inches), 1916 - 1950

Cambridge

	Daily Totals	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	All Months
IV	2.50													
	2.40													
	2.30													
	2.20													
	2.10													
	2.00								1					1
	1.90							2	1					3
	1.80							2	1					3
	1.70					1		2	1	2				6
	1.60					1		4	2	2				9
	1.50				1	1		4	2	3				11
	1.40				1	1		6	3	4	1			16
	1.30				1	1	1	7	5	4	1			20
	1.20				1	1	1	8	5	4	1			21
	1.10				2	1	2	9	5	5	3	1		28
	1.00	1			2	2	2	14	7	9	3	3		43
	0.90	2		1	2	3	3	17	11	12	3	3	2	59
	0.80	7	1	1	4	4	5	22	13	13	5	4	2	81
	0.70	9	1	5	6	9	6	25	14	16	8	8	2	109
	0.60	12	5	7	9	13	9	31	18	23	25	18	4	174
	0.50	20	10	14	17	28	15	48	21	35	32	30	11	281
	0.40	27	19	25	29	43	25	55	36	49	42	43	22	415
	0.30	60	45	44	58	72	54	88	66	80	79	75	54	775
	0.20	151	104	86	129	112	113	165	130	139	157	150	121	1557
	0.10	272	199	175	243	210	196	247	222	205	227	257	238	2691
IV	0.005	563	435	406	481	390	372	438	435	428	442	519	532	5441
* VI	0.004	522	554	679	569	695	678	647	650	622	643	531	553	7343
Total No. of days		1085	989	1085	1050	1085	1050	1085	1085	1050	1085	1050	1085	12874

* Including rainless days